



Beam-Switch Transient Effects in the RF Path of the ICAPA Receive Phased Array Antenna

O. Scott Sands
Glenn Research Center, Cleveland, Ohio

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

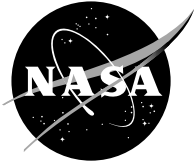
- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at <http://www.sti.nasa.gov>
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at 301-621-0134
- Telephone the NASA Access Help Desk at 301-621-0390
- Write to:
NASA Access Help Desk
NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076



Beam-Switch Transient Effects in the RF Path of the ICAPA Receive Phased Array Antenna

O. Scott Sands
Glenn Research Center, Cleveland, Ohio

National Aeronautics and
Space Administration

Glenn Research Center

Acknowledgments

The author would like to acknowledge the assistance and support of those who aided in the design and execution of the test and who encouraged and supported the effort. Kevin Lambert and Sandy Johnson helped with the data collection. Roberto Acosta and Rich Reinhart provided valuable comments, insights, and critiques to the report.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

Available electronically at <http://gltrs.grc.nasa.gov>

Beam-Switch Transient Effects in the RF Path of the ICAPA Receive Phased Array Antenna

O. Scott Sands
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Introduction

Phased Array Antennas (PAA) have been proposed for use in space communications at high frequencies (K/Ka band) and at high modulation rates (> 500 Mbps) [Zillig_etal97, Warshowsky_etal98]. When the beam of a PAA antenna is switched from one pointing direction to another, transient effects in the RF communications channel are observed. Such transient effects in the RF channel can be attributed to electrical ringing of the antennas phase shifters or to system implementation effects such as the non-simultaneous switching of the phase shifters. In particular, testing described here has revealed implementation-specific transient effects in the RF channel that are associated with digital clocking pulses that occur with transfers of data from the Beam Steering Controller (BSC) to the digital electronics of the PAA under test. Effects of the digital clocking pulses are observed prior to the actual occurrence of the beam-switch and are shown to have a significant affect on the RF path of the system. The observed changes to the RF channel will clearly increase average Bit Error Rate (BER) in the individual symbols occurring during the beam-switch transient events, however, a potentially more serious effect is the loss of receiver synchronization with the communications signal brought by the transients.

Synchronization loss at the frame level requires re-acquisition and thus induces a burst of symbol errors. It is therefore possible for a relatively short beam-switch transient to cause extended bursts of errors that, in turn, significantly degrade composite BER. The lower the spacecraft altitude, the more beam switching occurs and the shorter the flyover time. Thus, the potential exists for synchronization-loss-induced burst errors to contribute to system BER increases with decreasing spacecraft altitude. Furthermore, note that the beam switch rate is highest at spacecraft zenith. Thus, the potential for beam-switching induced errors appears to be greatest when slant range is the least and, by extension, E_b/N_0 is the greatest.

The objective of beam-switch transient testing is, in general, to assess the extent of effects of beam switching on a fully integrated PAA-based communications links. The tests described in this report provide an initial assessment of the beam-switch phenomena by digitally acquiring time series of the RF communications channel, under CW excitation during the period of time that the beam-switch transient occurs. The main result of the testing described here is the discovery of the observed effects of beam-switch transients on the RF channel. The testing described here supports future BER-level testing of transient phenomena by demonstrating the existence of beam-switch transients in the RF path of a PAA link.

Testing

The tests described here are focused on analyzing transient phenomena in phased array antenna systems. The tests are performed on an antenna developed by Boeing Aerospace, commonly known as the Integrated Circuit Active Phased Array (ICAPA) antenna [Erickson94]. Testing occurred in the Far Field Antenna range at NASA Glenn Research Center in Cleveland Ohio [Terry92]. In these tests a high-speed

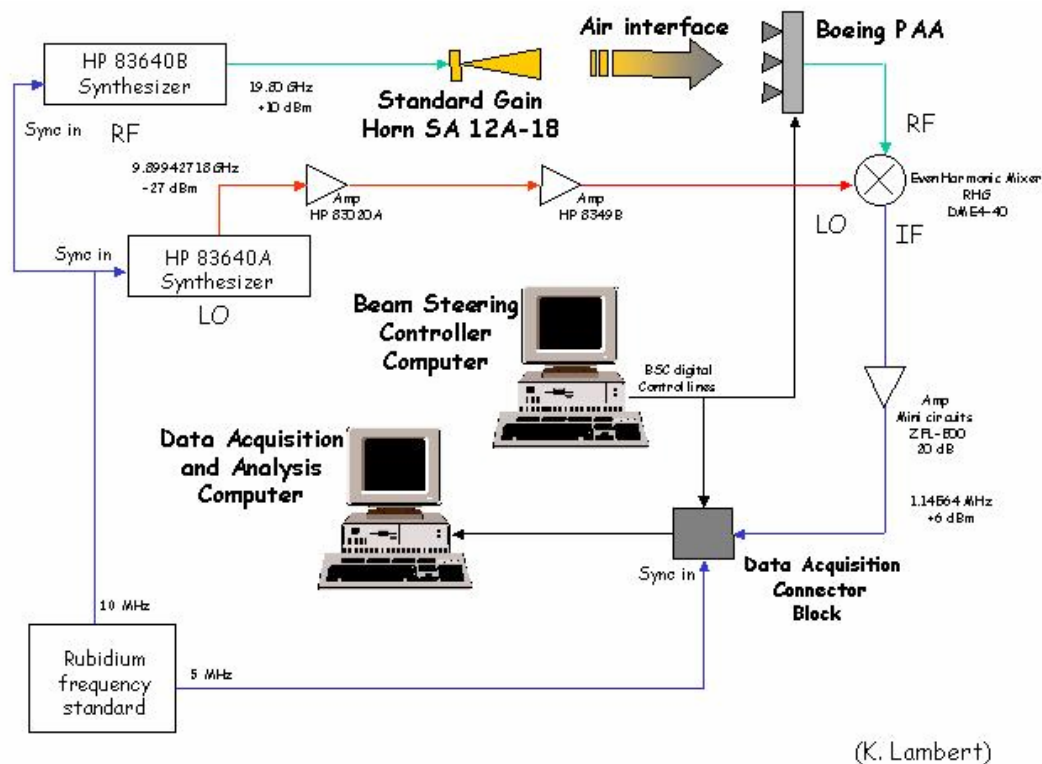


Figure 1: Block diagram of laboratory equipment used for RF transient testing.

data acquisition system is used to capture time series of the receive antenna RF output during a beam switch. These time series data are collected while the RF channel is under CW excitation at the center frequency of the array. Data collected during these tests support systems-level statistical analysis of a PAA rather than detailed component-level analysis of specific physical or electrical aspects of the antenna. The analysis reveals effects of the end-to-end antenna system that occur during beam switching and that are unpredicted by component-level analysis.

The test setup includes a fixed horn transmitter with the ICAPA antenna signal being detected in a 'semi-synchronous' homodyne receiver. In the test an SA 12A-18 standard gain horn is driven by an HP 83640B frequency synthesizer with a 19.8 GHz sinusoidal signal at approximately +10dBm to produce excitation for the receive array. A beam-steering controller, hosted in a PC computer, controls the ICAPA antenna and the RF signal from the ICAPA antenna is mixed with a 9.899 GHz 'LO' signal from a second HP83640 frequency synthesizer. As the mixer (an RHG DME4-40) is an even-harmonic mixer, the LO frequency is chosen to be approximately half of the frequency of the signal from the transmitting horn. The signal resulting from the mixing process is amplified with a Mini Circuits ZFL-500, providing approximately 20 dB of gain, to produce a signal of 1.14564 MHz at about +6 dBm. A National Instruments NI-DAQ PCI-6111 data acquisition card is used to measure this downconverted signal. This card requires a signal on the order of 1 volt peak-to-peak and is operated at its maximum sampling frequency of 5 MHz. Buffer size limitations within the NI-DAQ card limit time series collection to 32000 points (about 7 ms.). This period appears to be sufficient to observe all of the phenomena associated with beam switching. The amplitude and frequency of the downconverted signal are for accurate sampling by the data acquisition card. The data acquisition card and both frequency synthesizers are synchronized with a rubidium frequency standard. In order to ensure that data is captured during the transient event, the data acquisition card is 'triggered' by the digital control line that is asserted to command a beam-switch in the array (i.e. the 'pb4' signal, pin23 in the J2 connector.). The test system is illustrated in Figure 1.

The BSC for this array is, currently, limited to changes in the beam pointing direction of either 1 degree or 10 degrees in either the azimuth (theta) or elevation (phi) directions of a spherical coordinate system. Under this system, the azimuth (or theta) component indicates the angle between a projection of the beam-pointing vector, onto the x-y plane, and the positive x-axis, measured in the CW direction. The elevation (or phi) component indicates the angle that the beam-pointing vector makes with the positive z-axis. In the subsequent data analysis, statistics of the beam-switch transients are compared to relative changes in antenna pointing, as measured by the angle between initial and final pointing angles. Note that these angular changes may be significantly different from the changes in either of the spherical azimuth/elevation coordinates used in the ICAPA array coordinate system. Other antennas have adopted an “alpha/beta” coordinate system. In such a coordinate system the azimuth (or alpha) component indicates the angle that the pointing vector forms with the y-z plane and the elevation (or beta) component indicates the angle that the pointing vector forms with the x-z plane. Under the alpha/beta system, changes in pointing direction are related to changes in the pointing angle coordinates via the spherical version of the Pythagorean theorem.

Data Collection

The testing provides a survey of beam-switch transients over a large number of beam angular changes and a selection of three different physical pointing angles of the antenna boresight. The three angles are all at 0 degrees elevation and at 0, -19 and -50 degrees azimuth (antenna-pedestal coordinates.) Transients are collected for beam switches of both 1 degree and 10-degree increments. Beam switching occurs in both the 'forward' and 'reverse' directions in both azimuth and elevation. The selection of increments and directions is restricted by the current configuration of the beam steering controller.

For each physical pointing angle the beam is initially pointed at antenna boresight by adjusting the pointing angle of the PAA electronically. From this point a series of seven 1-degree transitions are made in either the azimuth or elevation direction. A time series, containing a beam-switch transient event is

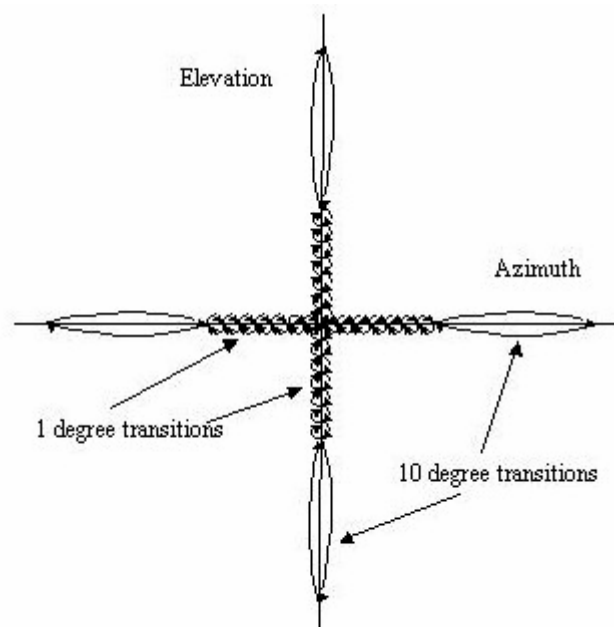


Figure 2: Pattern of beam transitions from the central pointing angle.
Receive antenna central angle is set to point directly into transmit horn.

collected for transition of the beam. After the seven 1-degree changes are made a 10-degree change in the beam is made in the same direction as the preceding changes. As the antenna beamwidth is approximately 10 degrees, the large changes provide data for 'worst case' considerations and represent the case when reception changes from main beam to sidelobe conditions, as might occur if the beam were to be time-multiplexed. Also included in the survey are large, 10-degree, changes that occur within the beam. Under these within-beam transitions, beam pointing changes from 'one side' of the beam to the other. Once the sequence of beam changes in the outbound direction is completed, the pattern of beam changes is reversed until the beam returns to antenna boresight. The pattern is repeated for each of the other three directions. The patterns of beam switches executed in these tests are illustrated in Figure 2. In this figure, each arc represents a beam change and the center of the diagram corresponds to antenna boresight. Note that the large within-beam transitions are not depicted on this diagram. In order to assess the repeatability of the experiment, the beam-switch transient corresponding to each transition is collected twice to form total set of 408 transients.

Observations, processing and analysis

Examples of the downconverted time series containing beam switch transients are illustrated in Figure 3(a) for a small (1 degree) change in steering angle and Figure 3(b) for a large (10 degree) change in steering angle. The physical pointing angle for these examples is 0 degrees azimuth and elevation. Note that the instant of beam switching occurs approximately 4.39 ms from the beginning of the data collection interval.

The digitized signal from the test setup contains a large number of spectral lines that corrupt the measured signal. The graphic in Figure 4(a) is an estimate of the power spectral density of the signal, as estimated from the time series illustrated in Figure 3 (a). Note the presence of several spectral components below 0.5 MHz, 30 to 40 dB down from the main peak. These peaks are, presumably, due to non-linearities in microwave test-setup electronics, these lines may be aliased components of the signal, however, and they are sufficiently disjoint from the carrier to be filtered. The spectrum illustrated in Figure 4(b) shows the results of filtering the signal with a 6th order Butterworth filter with center frequency 1.25 MHz and 1 MHz bandwidth. Note that, while the bandwidth of the system has been reduced significantly, the interfering signal has also been reduced significantly.

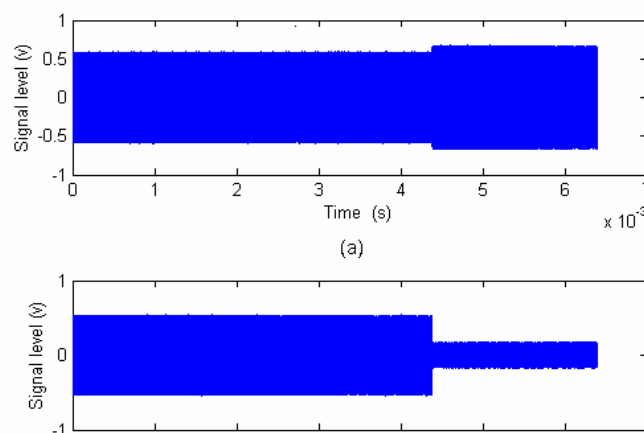


Figure 3: Examples of captured time series (a) small, 1-degree angular change toward antenna boresight (b) large, 10-degree angular change away from antenna boresight.

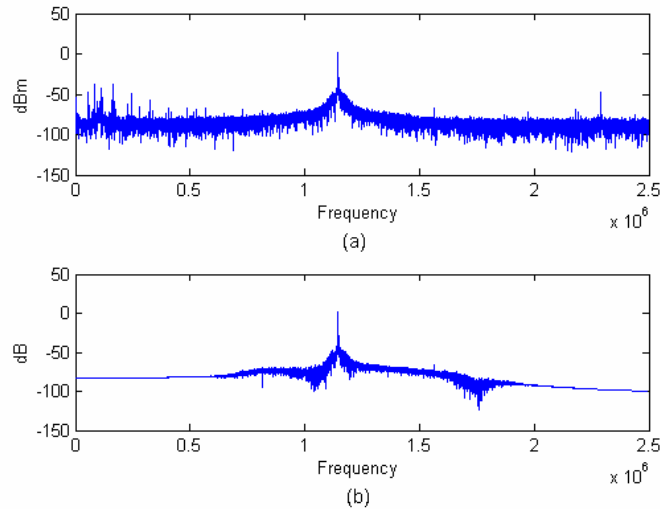


Figure 4: Power spectral density estimates of beam-switch transient time series (a) before filtering (b) after filtering.

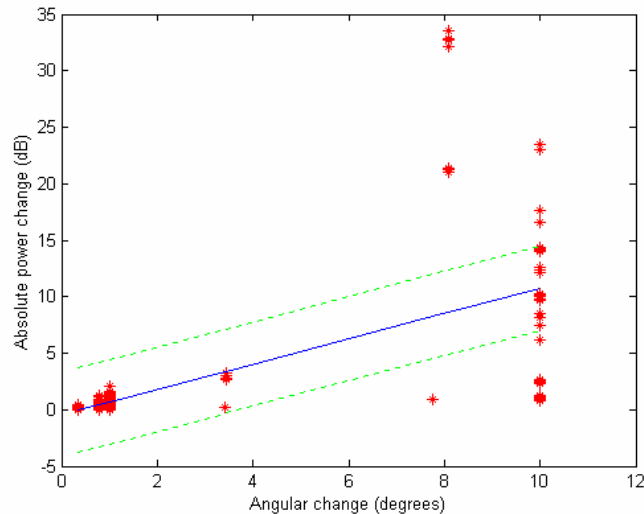


Figure 5: Change in power due to beam switching as a function of angular change in beam pointing direction.

Power changes

In both of the transients shown above, the level of the signal rises at the instant that the beam switch occurs. The time series in Figure 3(a) is associated with a change of 1 degree toward the antenna boresight and the large change is associated with a 10-degree change away from antenna boresight. The small change in antenna pointing results in a rise of 1.15 dB and the large change in antenna pointing produces a 10.25 dB drop in signal level. Figure 5 shows the distribution of absolute power changes as a function of angular changes for all data sets collected. Points on Figure 5 correspond to each of the beam-switch time series collected. Recall that two sets of data are collected in order to determine if the tests are repeatable. Agreement between the two sets of data for the power-change statistic is very good with 83% of the transients showing power changes within .1 dB of each other. The solid blue line denotes a fitting of the power change data to the commanded angular change with ± 1 sigma interval indicated with the

dotted green lines. The observed data show that increasing change in the beam pointing angle leads to increasing power level changes. Small changes in beam pointing produce small changes in power level changes and a tighter clustering around the expected power change. Larger changes in beam pointing produce less consistent results with variations of 30+ dB. Recall that the angular transitions consist of both within-beam transitions and main-beam-to-sidelobe transitions. The within-beam transitions are expected to have smaller changes in the power level, as the beam shape is fairly symmetrical while the main-beam-to-sidelobe transitions are expected to have large changes in power level. Thus the larger spreads in the power changes are expected for the high angular changes. Thusly, commanded angular change is not a particularly good regressor for the power change statistics.

Data clocking pulses

Prior to the instant that the beam changes direction, the BSC for the ICAPA array loads commanded phase shifts to the array through the digital control lines. Commanded phase shift data are loaded into the array during a series of eleven transfers of data from the BSC into the digital electronics of the array—one transfer for each row of phase shifters in the array. The effects of these transfers on the RF path of the array are observable in the captured time series. Figure 6 shows an estimate of the time-frequency distribution (short-time Fourier transform) of the transient given in Figure 3(b). Note the existence of the eleven broadband pulses prior to the beam-switch event. These pulses are associated with the loading of the phase shift data into the array electronics and are shown to cause significant changes in the RF channel.

Instantaneous Frequency Estimation

Changes to the RF channel brought by transient beam-switching effects are assessed in terms of the captured signal's deviation from the transmitted CW signal. These deviations are determined by

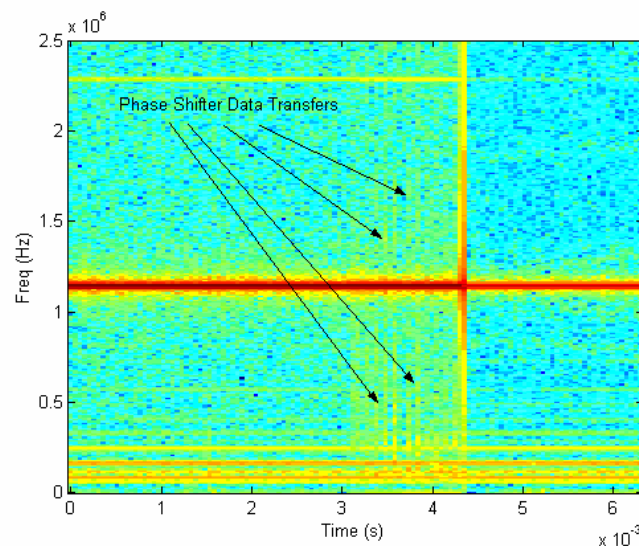


Figure 6: Time-frequency distribution of captured beam-switch transient. Broadband components are co-incident with data clocking pulses and beam-switch event.

estimating the Instantaneous Frequency (IF) of the digitized signal [Boashash92, Fertig_etal96]. The estimator for IF used here is the 'five point modified Prony' described in [Fertig_etal96]. This estimator produces a RMS dispersion of approximately 900 Hz for the signals processed here. This dispersion is approximately 1% less than that produced by a linear estimator of IF. The IF estimate for the time series given in Figures 3(a) and 3 (b) are given in Figures 7(a) and 7(b). Note that, in both figures, a large deviation from the carrier is produced at the instant that the beam switch occurs. For the small angular change, the deviation of the IF at the time of beam switch is on the order of 50 kHz while the IF deviation is on the order of 1 MHz for the large angular change. In Figure 7(a) the presence of large deviations (on the order of 3 to 5 kHz) are present in the IF plot. These deviations are co-incident with the data clocking pulses seen in Figure 6. These deviations are also present in the data shown in Figure 7 (b), however they are not visible due to the scale.

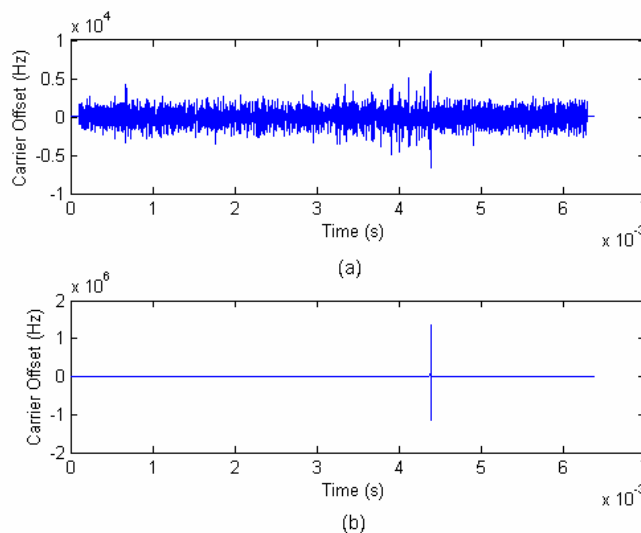


Figure 7: Examples of instantaneous frequency estimates for (a) small and (b) large angular changes.

IF and beam switch events

Large deviations in IF, associated with beam-switch events, are calculated by peak picking the 'envelope' of the IF estimate in an 80 microsecond interval surrounding the beam-switch event. These statistics are referred to as Maximum Frequency Deviations (MFD.) In Figure 8 MFD estimates from the two sets of data are shown in opposition to assess the repeatability of the MFD estimates. While correlation between MFD estimates is high (97.8% correlation) it is not as high as the correlation between estimates in power level change (99.9%) This fact suggests estimation error in the MFD is higher than in the power level change estimate.

Figure 9 shows the relationship between angular change and MFD. In Figure 9 the MFD statistics are graphed against the commanded angular beam pointing and data are indicated with red stars. The solid blue line denotes a fitting of the MFD data to the commanded angular change with ± 1 sigma interval indicated with the dotted green lines. Recall that commanded changes in beam pointing angle are in the spherical azimuth/elevation coordinate system described above while changes in beam location are indicted in terms of their absolute magnitude along great circle arcs and thus the angular changes are not identical to the 1 or 10 degree changes in beam pointing that are indicated in the spherical coordinates. A

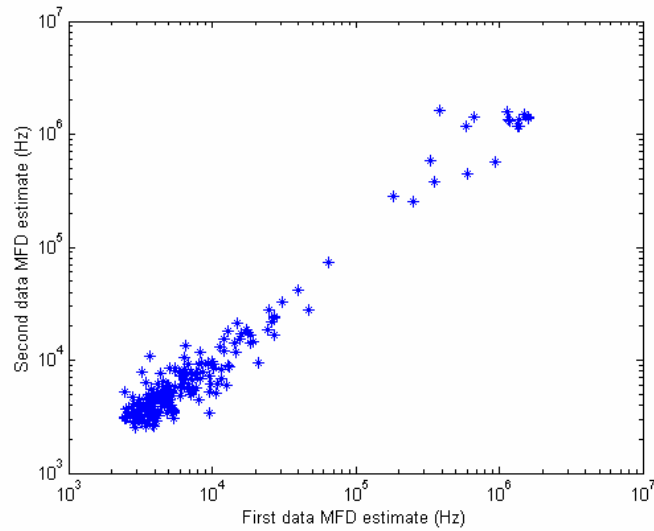


Figure 8: Comparison of first and second estimates of Maximum Frequency Deviation associated with beam-switch events.

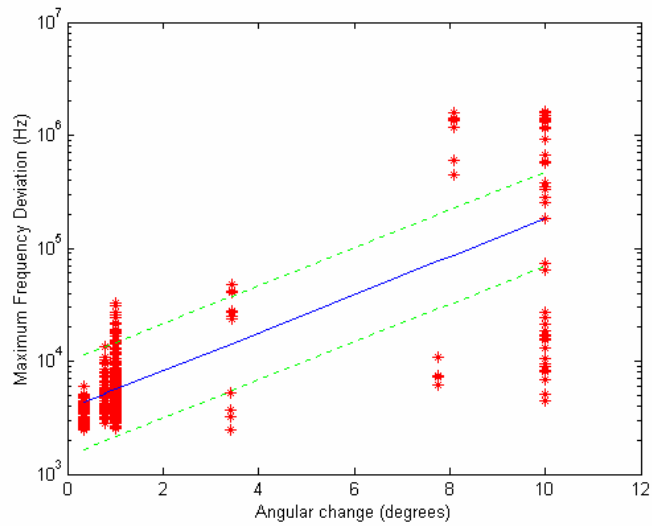


Figure 9: Maximum Frequency Deviation associated with beam-switch events as a function of angular change in beam pointing direction.

general trend of increasing MFD with increasing angular change appears in the data with a MFD value of approximately 4.36 kHz indicated at 0.34 degree and about 181 kHz at 10 degrees of change. Note that some of the IF deviations extend into the MHz range and thus challenge the ability of the experimental system to measure them. The deviations are over in approximately 10 to 20 microseconds in duration. Slewing rates for the beam-switch events are on the order of 10^{10} to 10^{13} Hz/sec. An exponential fit of the data yields a factor of 6.9 between the plus and minus 1-sigma levels. This yields a frequency spread of 9. KHz at 0.34-degree angular change and 406 kHz at 10 degrees angular change. Thus the spread in the MFD estimates is larger than mean deviation. The large estimation error, together with the tendency of the data to 'group' suggests that the dependence of instantaneous frequency deviation, solely on angular change, is too simplistic. Indeed, the clustering of the data into 'vertical' groups suggests that the

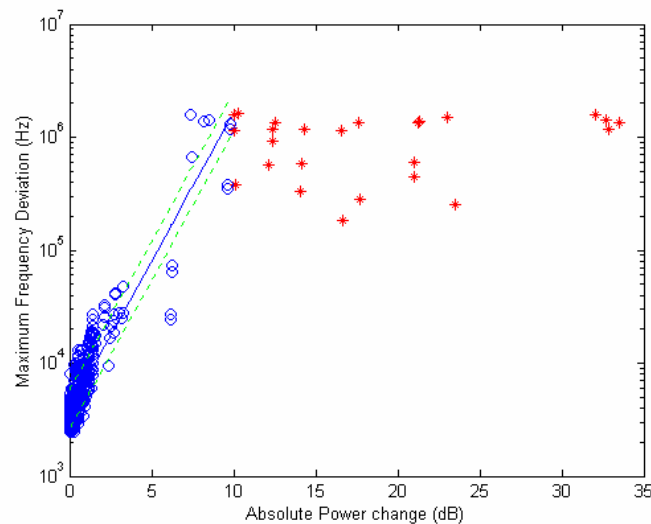


Figure 10: Maximum Frequency Deviation vs. change in power due to beam switching. Blue circles represent data that is within the range of the test setup.

magnitude of the frequency deviation may depend on the 'direction' of the change in pointing angle; angular deviation is not a good regressor for beam-switch MFD either. However, an examination of power change vs. MFD provides some hope!

In Figure 10, absolute changes in power level are shown graphed against beam-switch MFD estimates. Points on the graph represented by blue circles show small changes in power (less than 10 dB) while the red stars represent large changes in power brought by changes in beam pointing. For small changes in power, an exponential fit of the MFD data to the power change data is illustrated on the figure with a blue line and two dashed-green lines, representing the ± 1 sigma bars. Note that power-change is a much better predictor of MFD than is angular change—the use of power change results in a plus and minus spreading factor of only 2.2 (versus 6.9 for angular change.) Furthermore, Figure 10 shows that MFD is independent of power change for frequency deviations above about 1 MHz. This is consistent with the limitations on the measurement of frequency deviation given the 1 MHz limit on test system bandwidth.

IF and data clocking pulses

Large IF deviations are also observed co-incident with data clocking pulses described above. Figure 11 shows the distribution of occurrences of large deviations of the IF estimate within the entire data

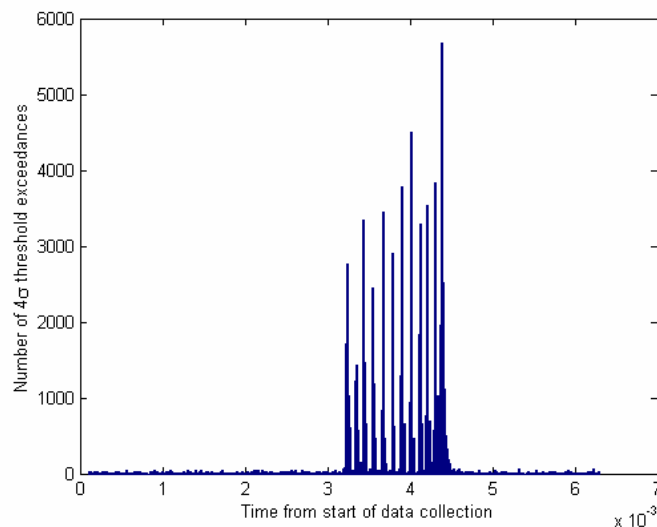


Figure 11: Distribution of 4-sigma threshold exceedances as a function of location.

acquisition window. A large deviation is defined here as one which exceeds four standard deviations of the local IF estimate (for data with small changes in beam steering, the RMS error of the IF estimate is approximately 900 Hz.) This distribution is given in the form of a histogram in which the abscissa corresponds to the location of the exceedance and the ordinate indicates the number of time samples that a threshold exceedance has occurred, over all of the collected data. Note that the bulk of the deviations in IF are co-incidental with data loading pulses. The time location of the 11 data clocking pulses are apparent in the figure together with the large number of threshold exceedances that occur at the instant of beam switch. Further note that the number of large deviations associated with each loading pulse is nearly as large as the number of deviations associated with the actual beam-switch event.

The magnitude of the maximum IF deviations associated with data clocking pulses are plotted as a function of their associated power change in Figure 12. Note that the IF deviations associated with data clocking pulses appear to be independent of power change for negative power changes and appear to be increasing with power change only for positive changes in power level. This can be explained by the fact that, in cases when there is a positive change in the signal power during the beam switch event, the prevailing SNR tends to be low before the beam switch (i.e. during the data clocking pulses). The lower SNR present before the beam switch tends to provide an amplifying effect on the IF deviations associated with the data clocking pulses and thus the increased IF deviations are an artifact of the processing. The frequency deviations associated with data clocking pulses provide a nominal (but significant) elevation of the prevailing IF estimate but are independent of angular change or power change. Note that 95% of the maximum IF deviations associated with data clocking pulses are between 2 and 10 kHz. As with the deviations in the IF estimate associated with the beam-switch event, changes in the IF estimate associated with data clock pulses are 10 to 20 microseconds in duration.

Conclusions

For the ICAPA array, beam switch transients and data clocking pulses spread the energy in the constant envelope RF signal across frequency and thusly reduce the possibility of accurately representing the signal by its phase or instantaneous frequency. For transients at the instant of beam switching, the change in power is to manifest itself in large increases in the deviation of the RF carrier. These deviations increase with the magnitude of the beam shift. The largest frequency deviations are associated with changes in the beam-pointing angle that are roughly the size of the beamwidth and correspond to transitions from main-beam to sidelobe conditions for the static testing performed here. Such conditions are not expected during operation of the array in a communications link. Large changes in beam pointing are included in the analysis presented here to reveal the dependence of beam-switch transient effects on angular change and because 10-degree changes are the only changes larger than 1-degree in the beam-steering controller. These large changes in beam pointing induce frequency deviations that exceed the limit of the current test system. Slewing rates of the smaller deviations exceed 10^{10} and larger deviations exceed 10^{13} Hz/sec. While such rates will clearly break phase lock during the event, it is unclear if breaking carrier lock is sufficient to induce the need for frame reacquisition. Additionally note that the observed frequency deviations associated with the beam switch event are more strongly correlated with apparent power changes and thus the large frequency deviations appear to be artifacts of the abrupt power change that occurs due to the movement of the beam.

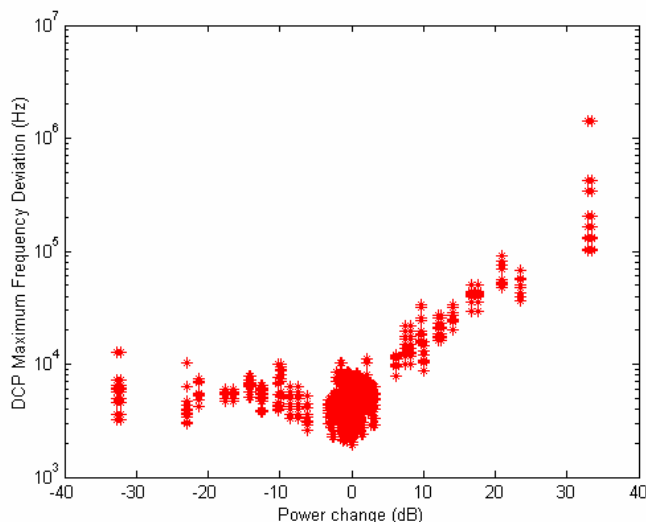


Figure 12: Maximum Frequency Deviation associated with data clocking pulses as a function of power change.

The more relevant phenomena uncovered by these tests are the data clocking pulses that occur prior to the actual beam-switch event. These pulses induce IF deviations that are similar in magnitude to the IF deviations associated with the beam switch event (for small angular changes.) However, these distortions of the RF channel are not limited to a single event. Rather, the data clocking pulses are associated with large deviations in the IF that are regularly spaced with a 10 to 20 percent duty cycle!

Recommendations

Due to the observation of transient effects in the RF channel of the array, it is recommended that BER testing of the link, in the presence of beam-switch transients should be conducted that assesses the impact of beam-switch transients in spaceborne communications links with real modems. In support of this testing it is recommended that a 'baseline' synchronization scheme, modeled after the actual modem to be used in the test, is devised and analyzed in order to provide a basis for the assessment of the likelihood of loss of frame synchronization. Finally it is recommended that the BSC be modified to incorporate the ability to include beam-switches that are other than 1 or 10 degrees.

References

- [Zillig_etal97] David Zillig, Kenneth Perko, Mark Burns and George Welti, "Feasibility of a Phased Array Antenna for Dual TDRSS/Direct-To-Ground Ka-Band Communications," Third Ka-Band Utilization Conference, September 15–18, 1997, Sorrento, Italy.
- [Warshowsky_etal98] J.D. Warshowsky, J.J. Whelehan and R.L. Clouse, "High Rate User Phased Array Antenna for Small Leo Satellites," Fourth Ka-Band Utilization Conference, November 2–4 1998, Venice, Italy.
- [Erickson94] Grant Erickson, "ICAPA Receive Antenna System Operators Instruction Guide," Boeing Defense & Space Group, Kent, WA 98032, January 1994.
- [Terry92] John D. Terry, "Operating and Service Manual for the NASA Lewis Automated Far-Field Range, NASA Technical Memorandum 105343, January 1992.
- [Boashash92] Boulem Boashash, "Estimating and Interpreting the Instantaneous Frequency of a Signal--Part 1: Fundamentals," Proceedings of the IEEE, Vol. 80, No. 4, April 1992.
- [Fertig_etal96] L.B. Fertig and J.H. McClellan, "Instantaneous Frequency Estimators with Comparisons to the DESAs," IEEE Signal Processing Letters, Vol. 3, No. 2, February 1996.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 2003		3. REPORT TYPE AND DATES COVERED Technical Memorandum
4. TITLE AND SUBTITLE Beam-Switch Transient Effects in the RF Path of the ICAPA Receive Phased Array Antenna			5. FUNDING NUMBERS WBS-22-322-70-01	
6. AUTHOR(S) O. Scott Sands				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration John H. Glenn Research Center at Lewis Field Cleveland, Ohio 44135-3191			8. PERFORMING ORGANIZATION REPORT NUMBER E-14145	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001			10. SPONSORING/MONITORING AGENCY REPORT NUMBER NASA TM-2003-212588	
11. SUPPLEMENTARY NOTES Responsible person, O. Scott Sands, organization code 6120, 216-433-2607.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category: 17 Available electronically at http://gltrs.grc.nasa.gov This publication is available from the NASA Center for AeroSpace Information, 301-621-0390.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) When the beam of a Phased Array Antenna (PAA) is switched from one pointing direction to another, transient effects in the RF path of the antenna are observed. Testing described in the report has revealed implementation-specific transient effects in the RF channel that are associated with digital clocking pulses that occur with transfer of data from the Beam Steering Controller (BSC) to the digital electronics of the PAA under test. The testing described here provides an initial assessment of the beam-switch phenomena by digitally acquiring time series of the RF communications channel, under CW excitation, during the period of time that the beam switch transient occurs. Effects are analyzed using time-frequency distributions and instantaneous frequency estimation techniques. The results of tests conducted with CW excitation supports further Bit-Error-Rate (BER) testing of the PAA communication channel.				
14. SUBJECT TERMS Phased-array antenna; Transient; Communication			15. NUMBER OF PAGES 18	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT	